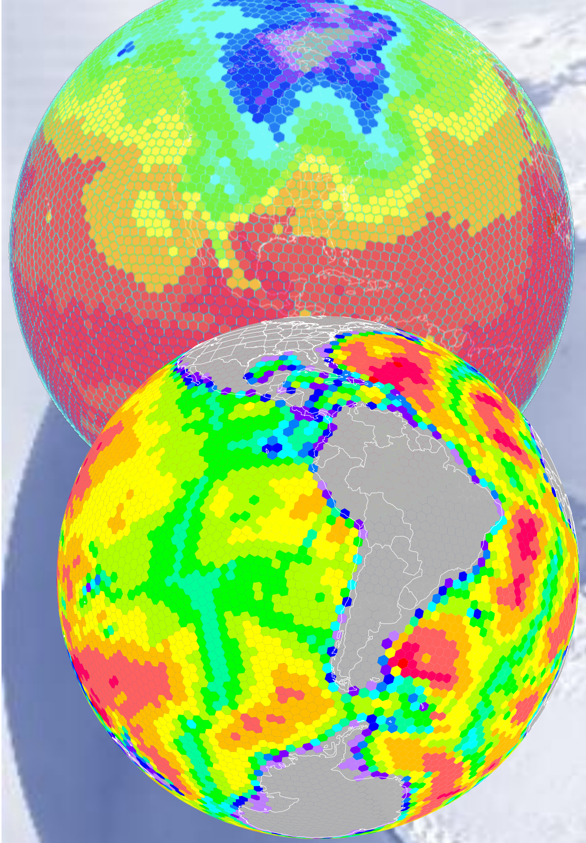
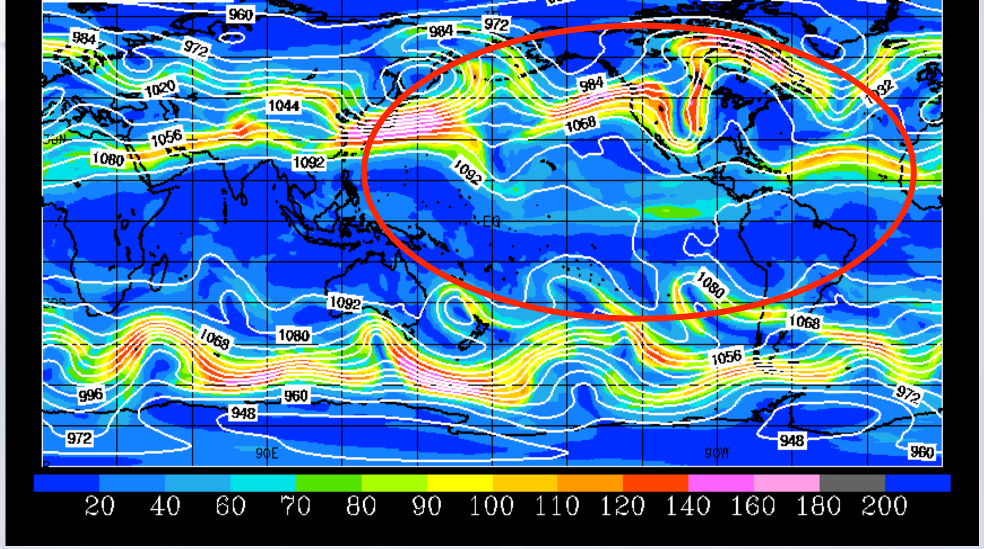




March 2012
N. American block

Identification of Predictability for Processes Related to Atmospheric Blocking *(Preliminary Results)*

Stan Benjamin

Shan Sun, Rainer Bleck, Haiqin Li, Ben Green, Georg Grell

NOAA Earth System Research Lab/GSD

Boulder, CO USA

NOAA MAPP Webinar
19 February 2016

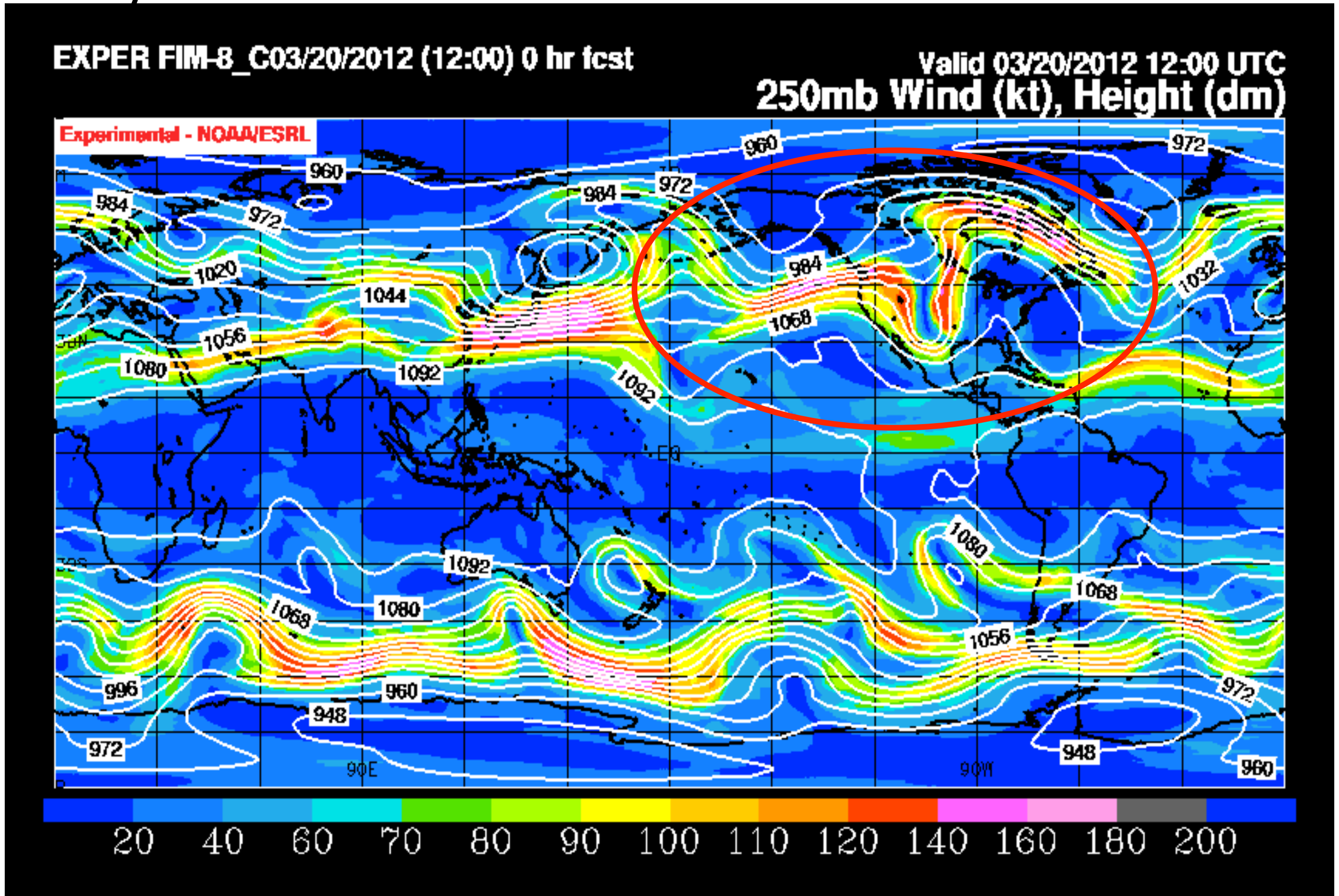
Episodic Weather Extremes from Blocking

Longer-term weather anomalies from atmospheric blocking

-Defined here as either ridge or trough quasi-stationary events with duration of at least 4 days to 2+ months

ESPC focus area #1

target: improved 0.5-6 month forecasts of blocking and related weather extremes (drought, flooding, extended cold/snow or heat)



NOAA/Navy/others Earth System Prediction Capability
ESPC focus target: improved 1-6 month fcst of blocking

Processes related to blocking onset, cessation, prolongation

Model component sensitivity

Process	Initial value – data assim	High-res Δx	Coupled ocean	Stochastic phys	Cloud/rad phys	PV cons. numerics	Chem/aerosol	Soil/snow LSM accuracy
• Extratropical wave interaction	✔	✔		✔		✔		
• MJO life cycle	✔	✔	✔	✔		✔	✔	
• Other tropical processes/ENSO	✔	✔	✔	✔			✔	
• Tropical storms and their extratropical transitions	✔	✔	✔	✔		✔	✔	✔
• Sudden stratospheric warming events	✔					✔	✔	
• Snow cover anomalies	✔						✔	✔
• Soil moisture anomalies	✔		✔		✔		✔	✔
• Cloud/radiation/temp patterns (avoid regions of SST bias, continental warm bias, etc.)					✔			

Hypothesis:

- Blocking predictability in models is related to predictability of related processes – MJO, stratospheric warming events, Rossby wave breaking, land-surface memory, etc.

Needed research - sensitivity of these processes to

- Subgrid-scale representation (convection, gravity wave drag, subgrid cloud, etc.), horizontal and vertical resolution, numerics.
- Full hindcast test period statistics. Key case periods 2012, 2010, 2013-14…

- Datasets
  - NOAA/NCEP's Climate Forecast System v2 (Saha et al 2014, J. Climate)
    - current NOAA seasonal prediction, control
  - Other NMME models + FIM-HYCOM atmospheric/oceanic (alternative grid structures in horizontal/vertical)
- Week 3-4 blocking process freq studies started- CFSv2, FIM-HYCOM

Blocking frequency as a function of global model resolution
Jung et al., 2012, *J. Climate*: High-res ECMWF experiments for **Project ATHENA**

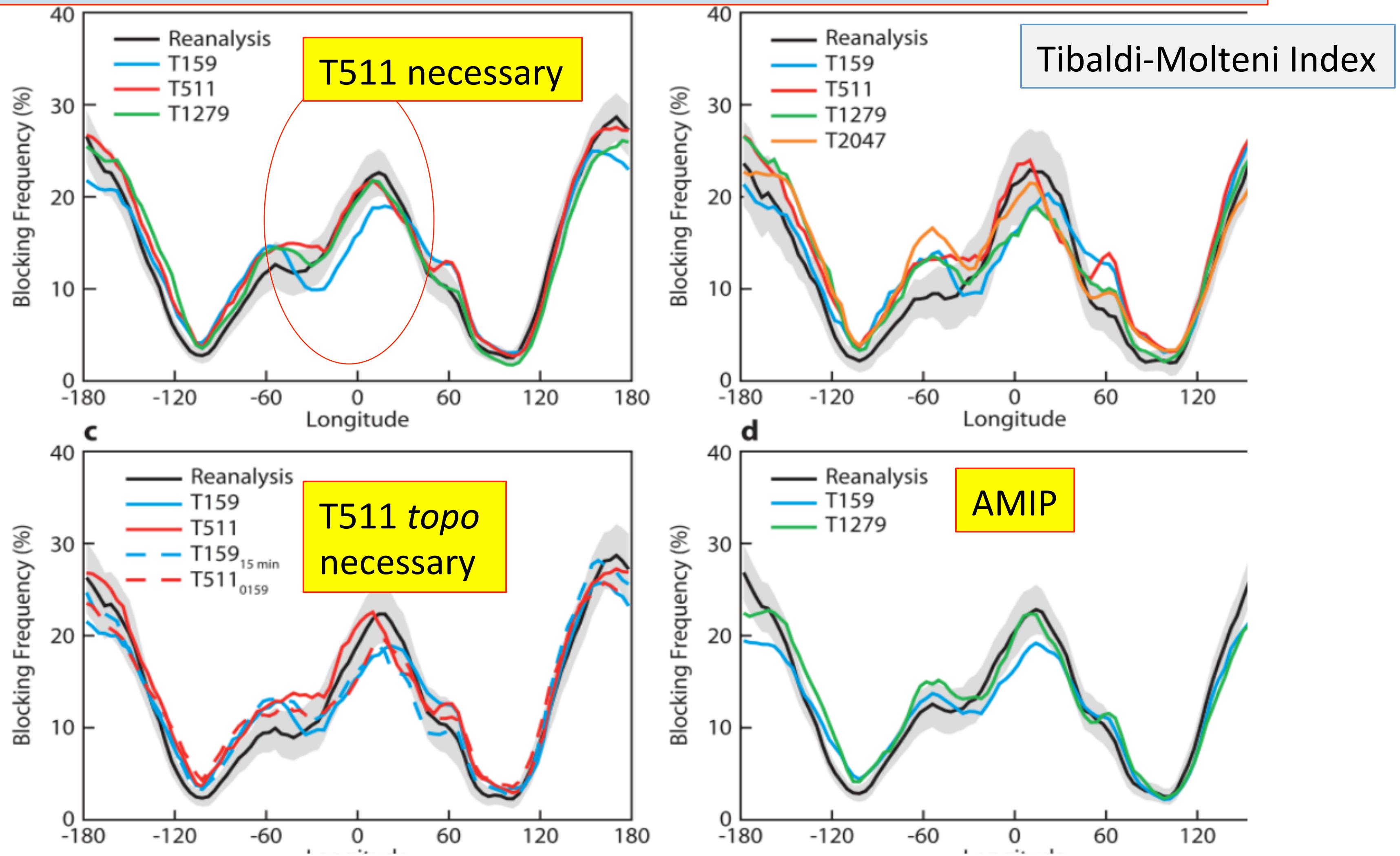


FIG. 8. Frequency of occurrence (in %) of days at which the wintertime (December–March) Northern Hemisphere midlatitude flow is blocked: (a) ERA reanalysis (black with 95% confidence level using a two-sided Student's *t* test), T159 (blue), T511 (red), and T1279 (green) for the period 1960/61–2007/08. (b) As in (a), but for the shorter period 1989/90–2007/08 and with T2047 results (orange) included. Results in (a) and (b) are based on 13-month integrations. (c) As in (a), but for the period 1980/81–2007/08 and at T159 (blue), T511 (red), $T159_{15min}$ (dashed blue), and $T511_{O159}$ (dashed red). (d) As in (a), but for AMIP-style experiments and the shorter period 1962/63–2006/07.

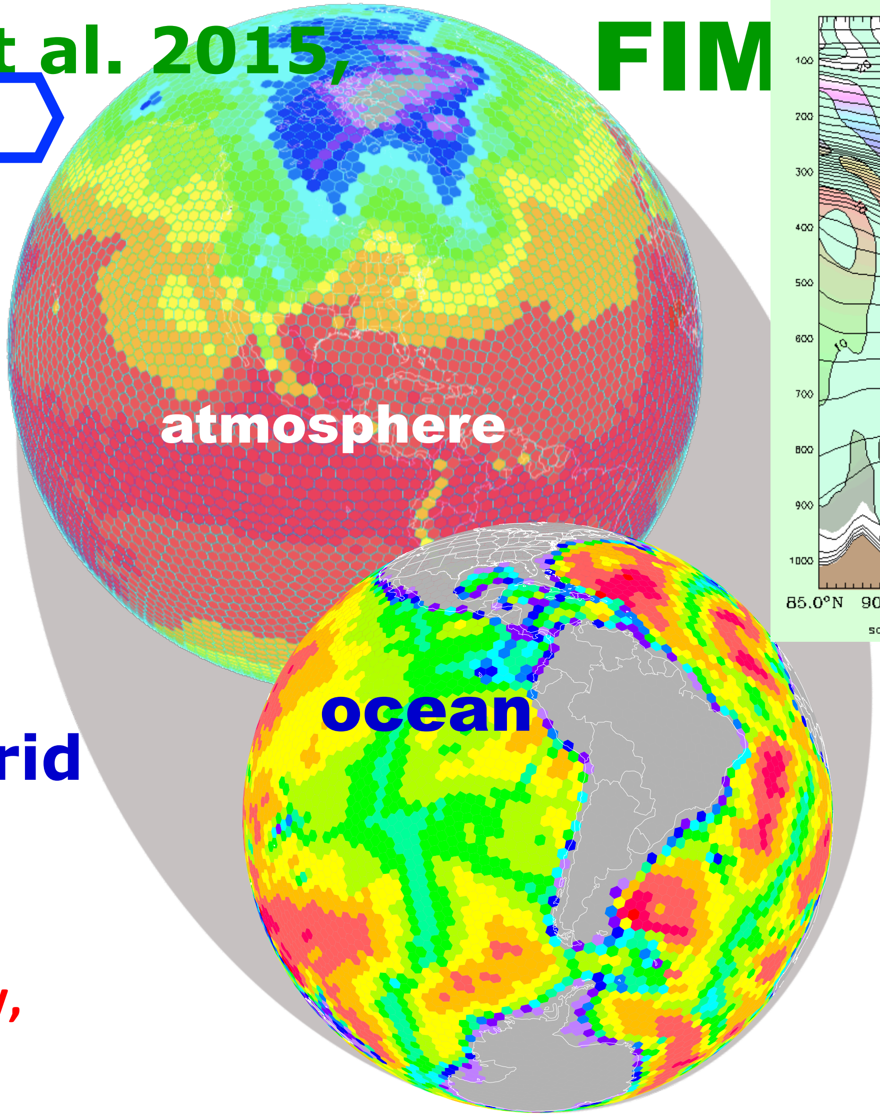
NOAA/ESRL global coupled model - θ – ⬡

FIM – Flow-following finite-volume Icosahedral Model - Bleck et al. 2015, *Mon. Wea. Rev.*

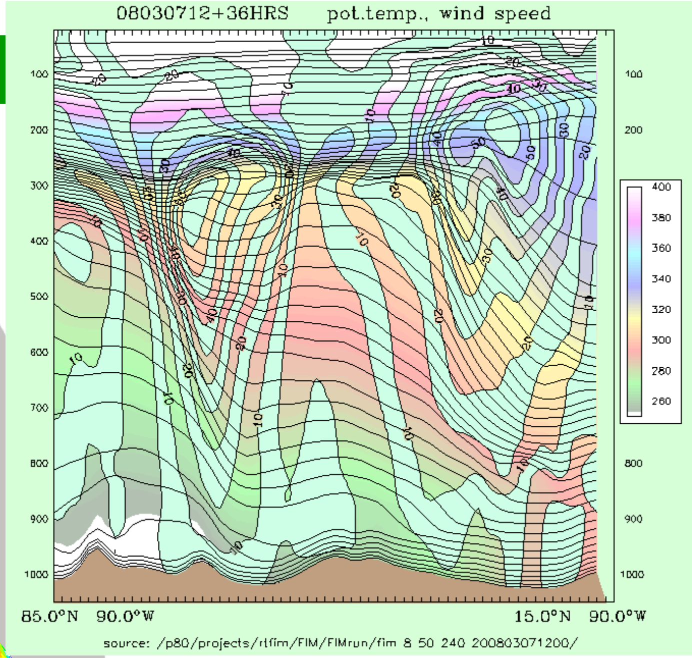
- “soccer-ball” quasi-uniform grid spacing ⬡
- Isentropic- θ /sigma (hybrid (ALE – arbitrary Lagrangian-Eulerian) adaptive vertical coordinate
- Extensive NWP testing as advanced baseline for NGGPS
- Experimental at ESRL – 15km, 10km, 30km resolution
- Inline chemistry option, coupling with HYCOM

HYCOM – (Icosahedral) Hybrid Coordinate Ocean Model

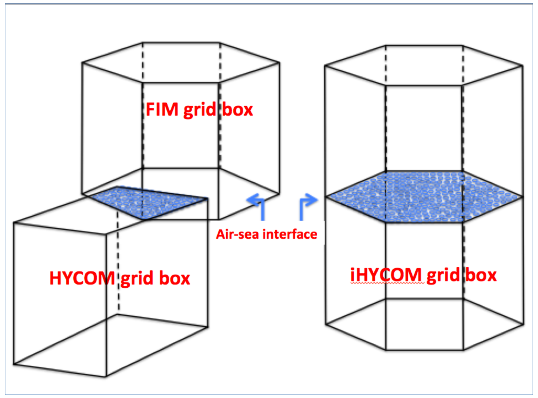
- Use of ALE vertical coordinate
- Development/testing at NCEP, ESRL, Navy, common vertical model
- ESRL - matched grid design to FIM for coupled ocean-atmosphere prediction system



FIM



iHYCOM



Example of mergers of multi-agency components for earth system models

Attribute / Model	CFS v2 Implemented March 2011	FIM/iHYCOM - 2015 (for initial 16-yr hindcast – 32-day duration)
Analysis resolution	38 km (T382)	Use CFSv2 initial conditions
Atmosphere model - resolution	100km (T126 – spectral) / 64 levs (sigma-p)	30km (icosahedral) / 64 levs (hybrid isentropic-sigma) - ALE
Model physics	GFS-2007/CFS - Variable CO2 (specified) AER SW and LW radiation Prognostic clouds and liquid water Retuned mountain blocking Convective gravity wave drag	Similar but updated to 2015 GFS physics suite including hybrid EDMF PBL Also with Grell-Freitas (2014) deep cum. (Gravity wave drag using incorrect parameters)
Ocean model	MOM-4 –global ¼ x ½ deg - tripolar Assimilation depth – 4737m	HYCOM – global (hybrid-isopycnal) - ALE (collaboration with Navy, NOAA/NCEP) 30km icosahedral – matched with atmos grid
Land-surface model (LSM) and assimilation	Noah LSM with USGS/CFS land-use, initialized with daily GLDAS . Ice - prognostic sea ice within MOM4	Noah LSM - Same as GFS MODIS land-use Ice - HYCOM energy loan
Coupling frequency	30 minutes	Every physics time step (3 min)

Similar / Different

Subseasonal datasets

- FIM-HYCOM coupled model reforecasts
    - Forecasts out to 32-day duration
    - 4x weekly – init times up to 06z Wednesday
    - 1999-2014 – 16-year period
    - CFSv2 initial conditions for atmosphere and ocean
    - 30km resolution – same icosahedral grid for atmosphere and ocean
    - Isobaric and isentropic data available
        - Allows accurate Tibaldi-Molteni (500 hPa Z) and Pelly-Hoskins (theta on PV=2 – tropopause) calculation
- CFSv2 coupled model reforecasts
    - Matched runs to FIM-HYCOM hindcast
    - Only isobaric data available – coarser PV=2 diagnostic

NWP testing informative for development of subseasonal-seasonal coupled models

Effect of alternative dynamic core (icosahedral, isentropic) from FIM

2015 500 hPa anomaly correlation

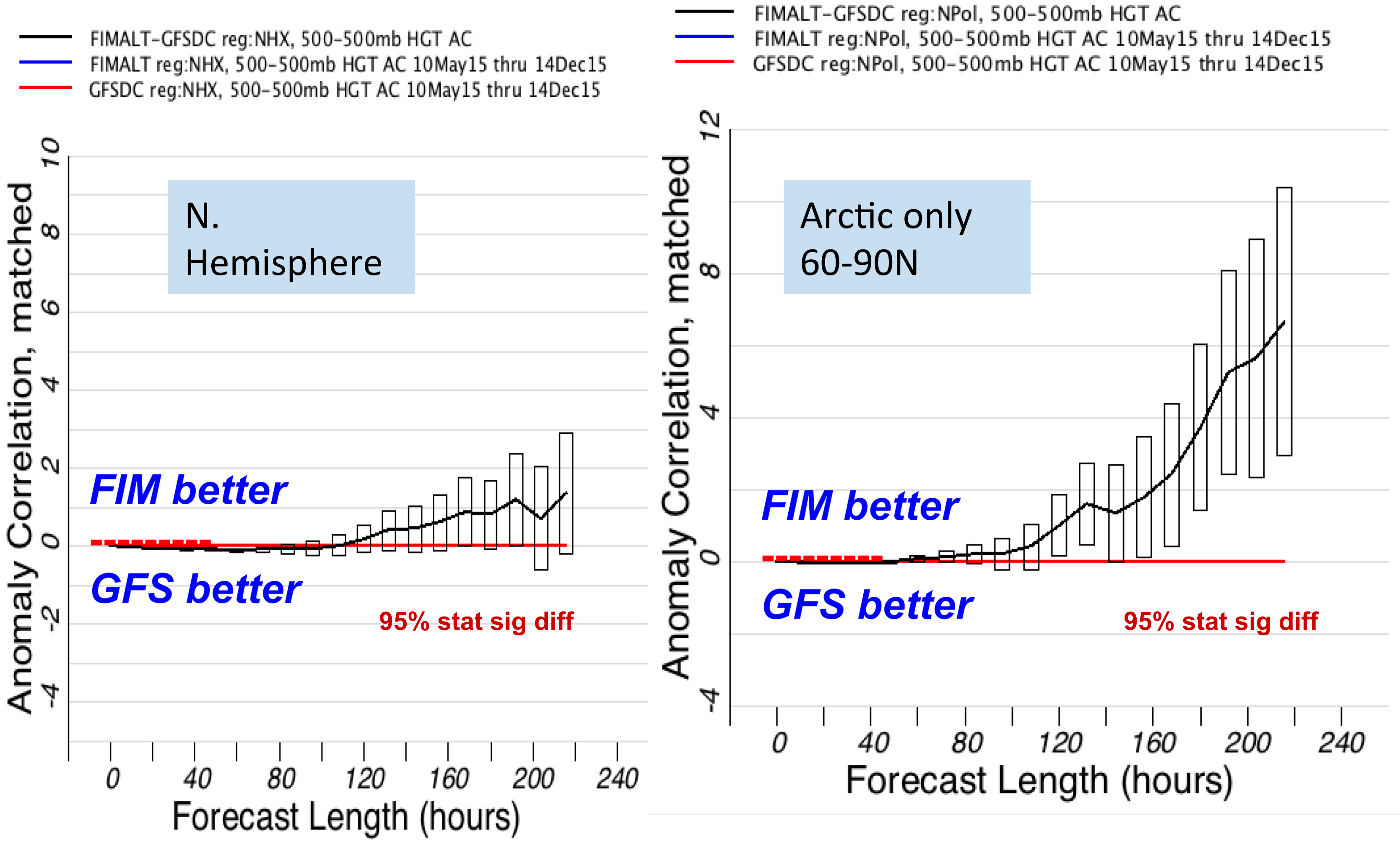
FIM-30km real-time vs. GFS operational

FIM using

- GFS physics,
- GFS initial conditions
- 64 levels like GFS

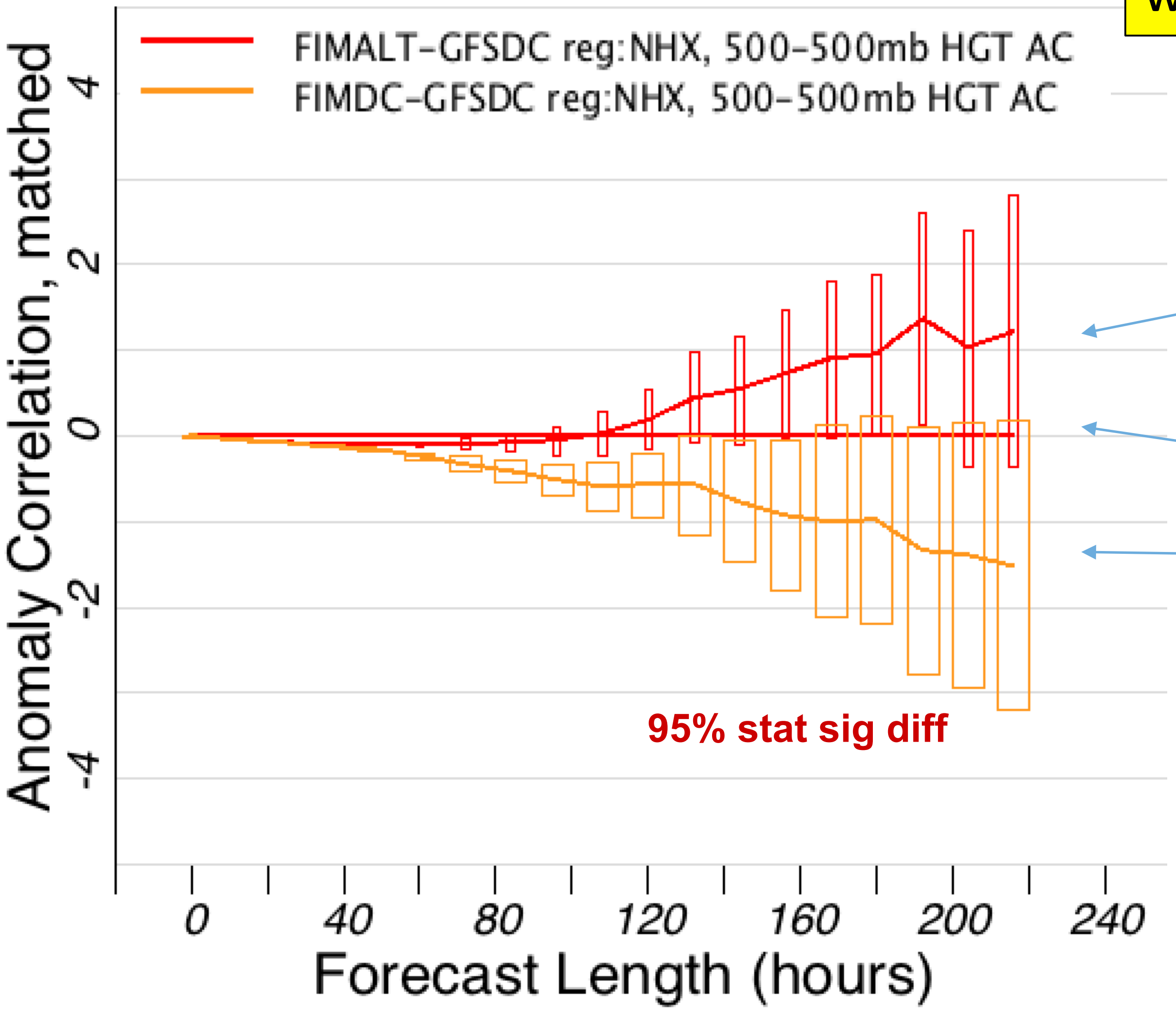
0-9-day forecast – May-Dec 2015

95% significance bracket



NWP testing informative for development of subseasonal-seasonal coupled models

500 hPa anomaly correlation
May – December 2015
GFS vs. FIM30km with 2 different gravity wave drag sets of parameters



<u>Difference in 500 AC skill vs. GFS oper</u>

FIM30km with T1534 GWD parameters

GFS-T1534 operational

FIM30km with T574 GWD parameters

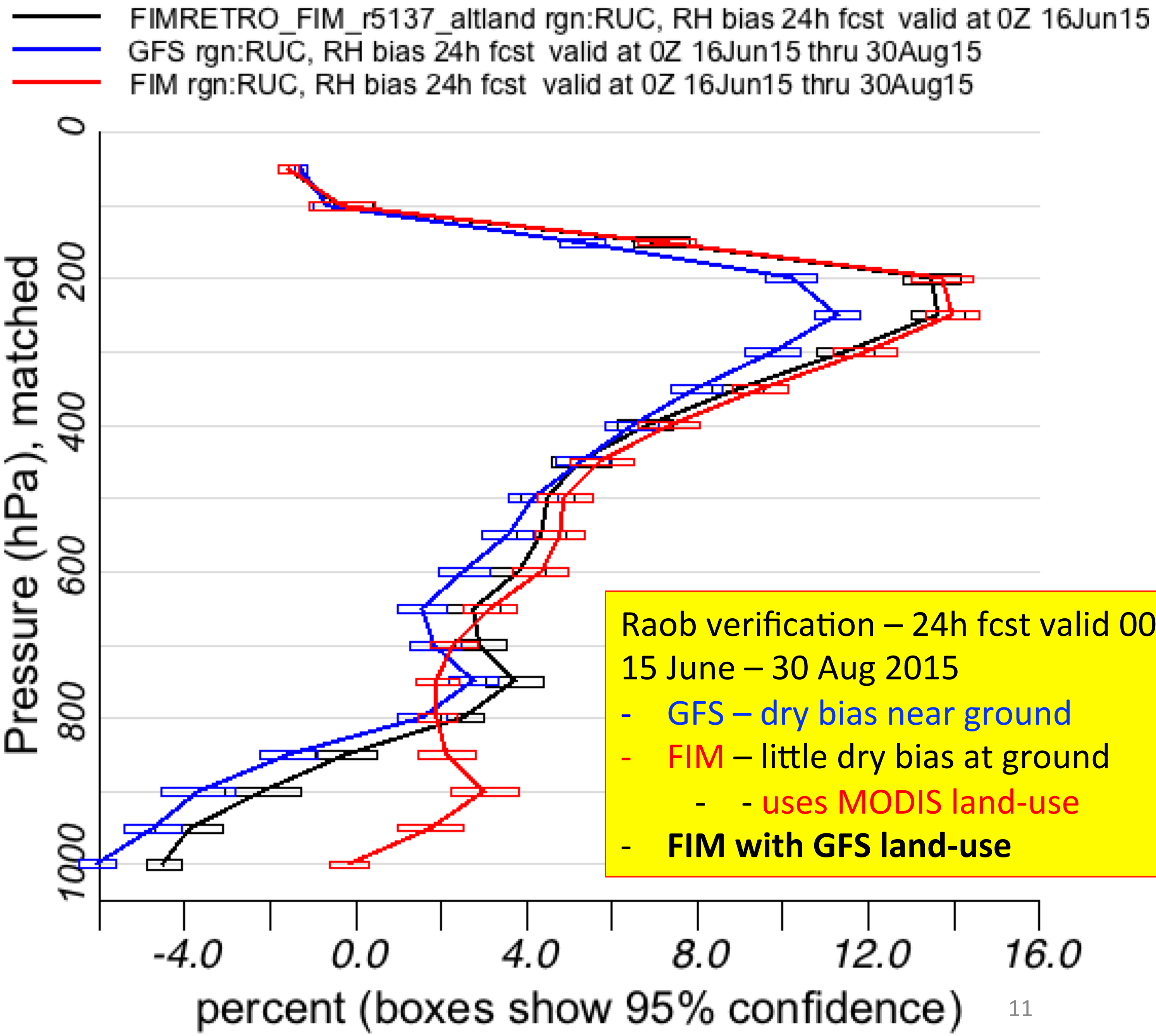
<u>Result from NOAA High-Impact Weather Prediction Project - FIM testing:</u>

GSD tests for use of GFS physics - *Recommend using same gravity wave drag parameters at 30km (or T574) as used at 13-15km (T1534)*

NWP testing informative for development of subseasonal-seasonal coupled models

Major problem with surface warm/dry bias in GEFSp and GFS

But why does FIM
(same 2015-GFS physics,
same GFS init conditions including soil moisture/LSM, 30km)
not show the same RH bias?



Raob verification – 24h fcst valid 00z 15 June – 30 Aug 2015

- GFS – dry bias near ground
- FIM – little dry bias at ground
  - - uses MODIS land-use
- **FIM with GFS land-use**

Overall blocking behavior

Indices for detecting blocks and breaking Rossby waves

Tibaldi-Molteni (1990)

- Detects reversal of north-south (~40N-~60N) height gradient on **500hPa** surface:

$$\partial \phi / \partial \varphi > 0$$

Pelly-Hoskins (2003)

- Detects reversal of north-south θ gradient on a **tropopause-level** PV=2 surface: $\partial \theta / \partial \varphi > 0$
- Favored jet latitude = f(longitude)

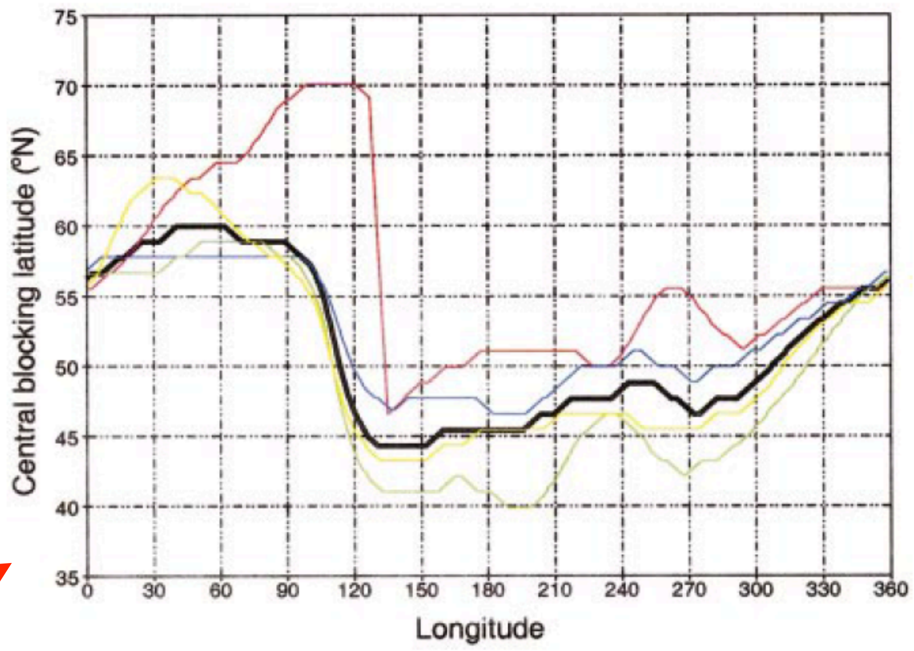
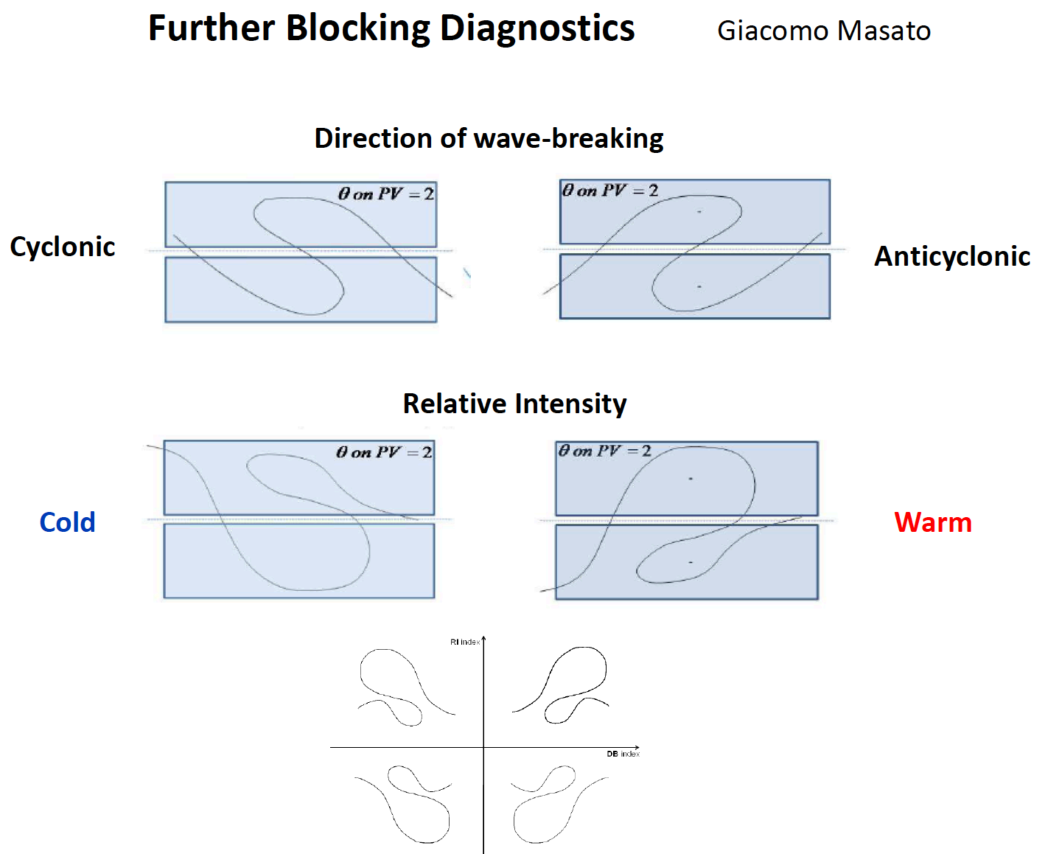


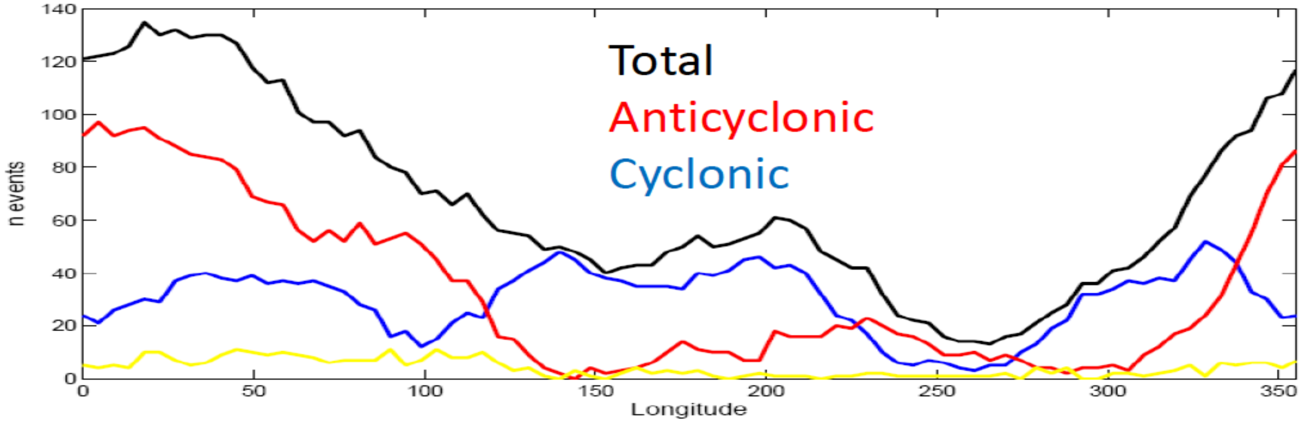
FIG. 4. The black line shows the central blocking latitude around the Northern Hemisphere calculated from the annual mean high-pass transient EKE ($m^2\ s^{-2}$) at 300 hPa taken from the ERA-15 dataset (1979–93 ECMWF Reanalysis). Colored lines show the seasonal variations in the central blocking latitude: Jun–Aug (JJA; red), Sep–Nov (SON; blue), Dec–Feb (DJF; green), Mar–May (MAM; yellow).

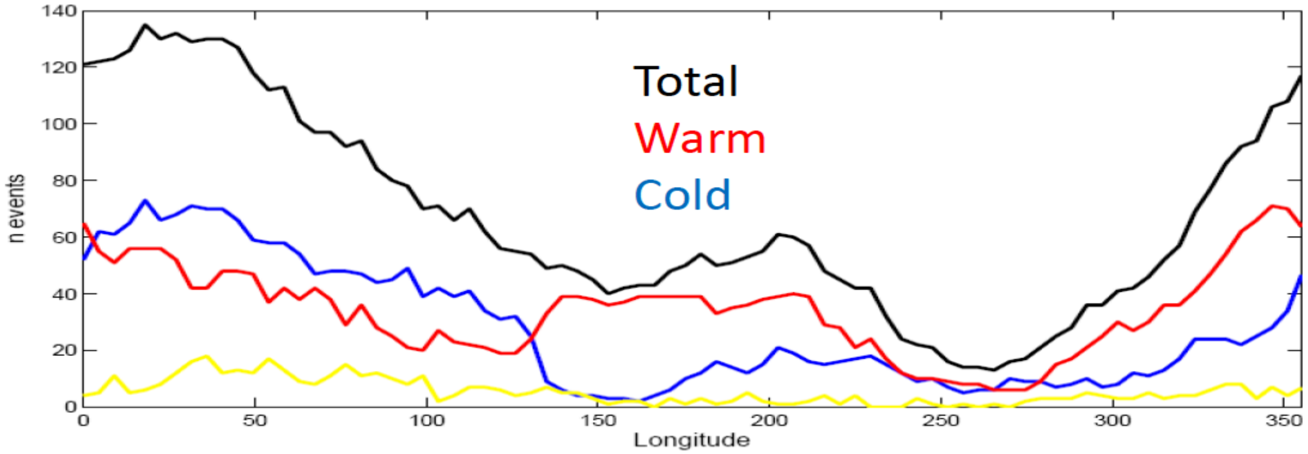
Other details involved for both blocking indices

Blocking frequencies (Pelly-Hoskins index) - f(latitude)

- Dynamic tropopause blocks much more common for Atlantic than Pacific



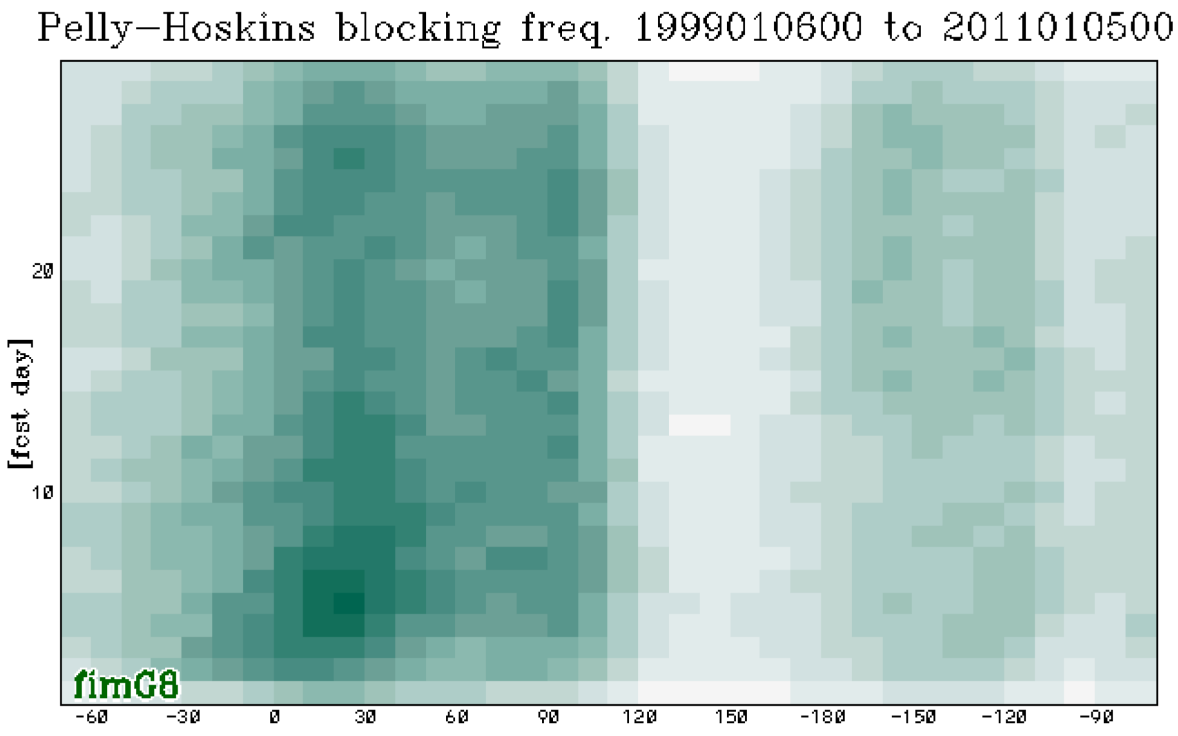


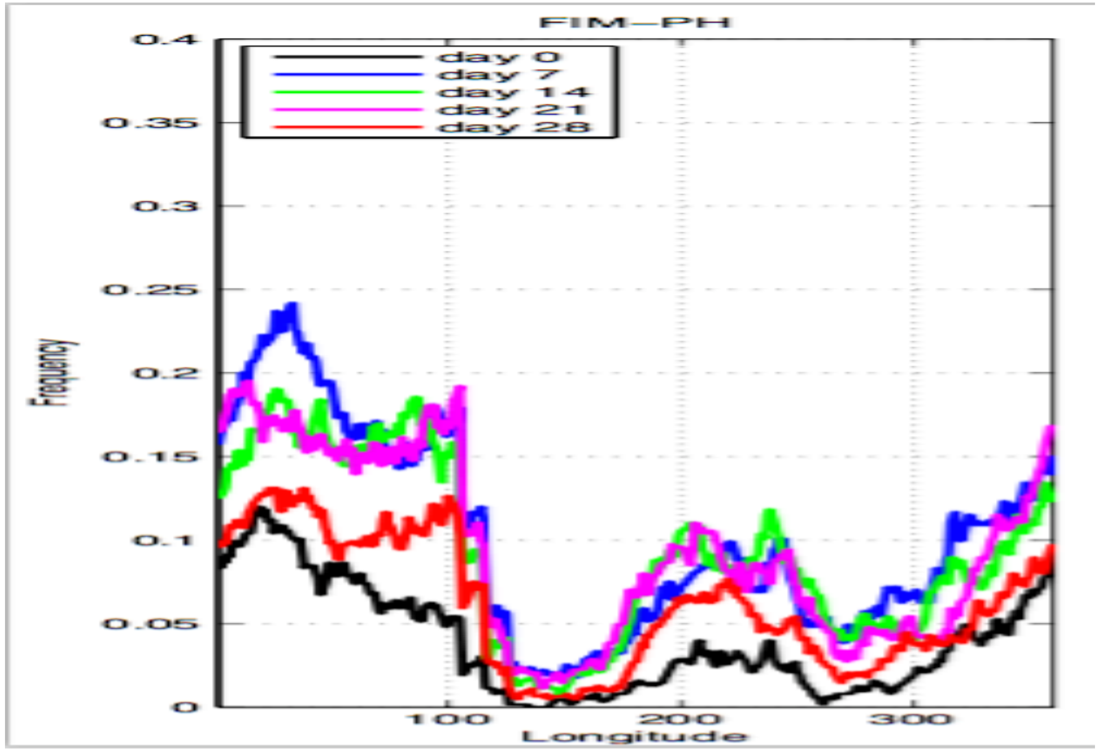


Blocking frequency over 1-30-day forecasts - Pelly-Hoskins

FIM-HYCOM coupled model experiments

- 1999-2011 retro experiments, 4x/week, 32-day, 30km

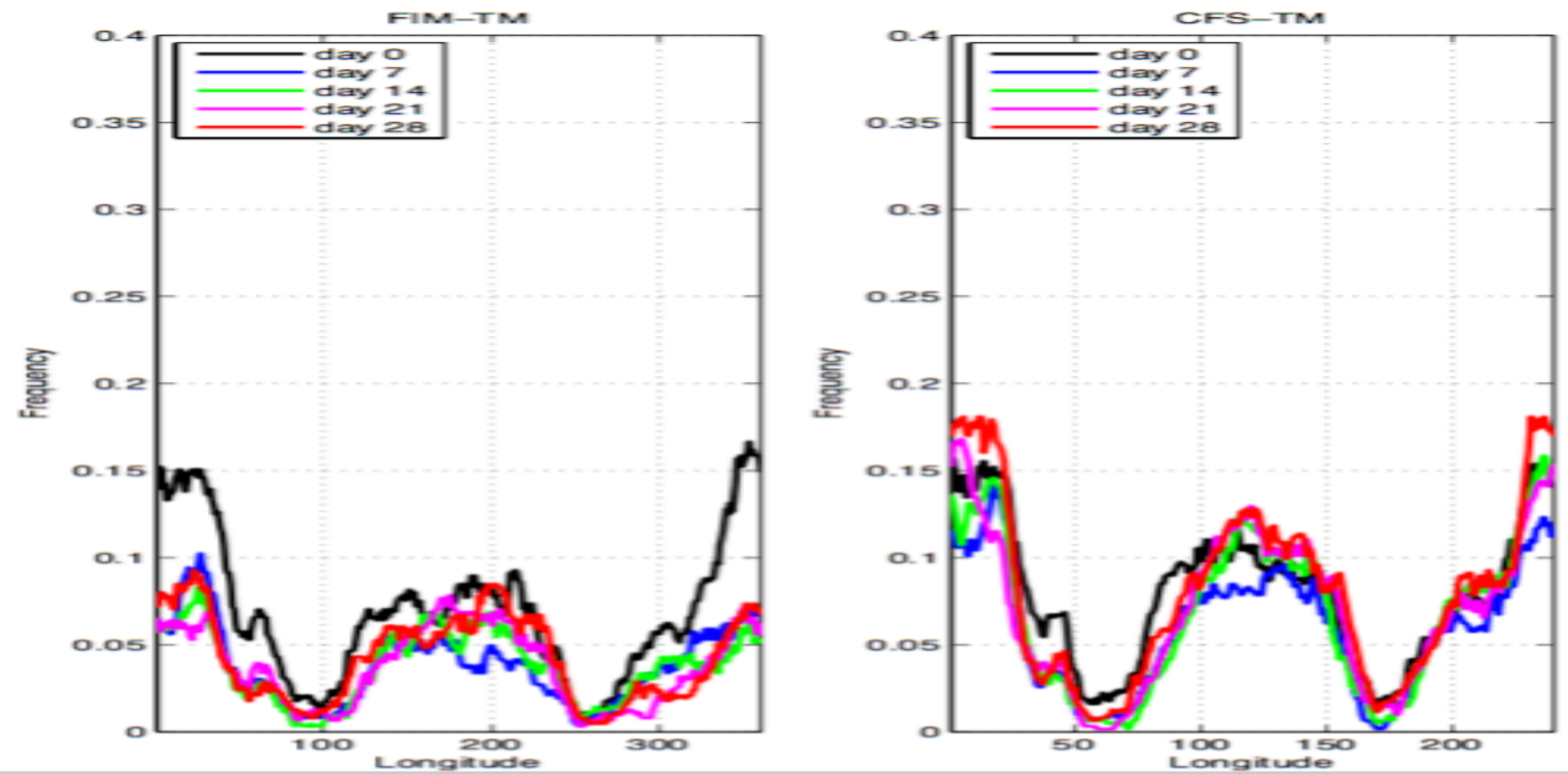




Blocking frequency over 1-28-day forecasts - Tibaldi-Molteni

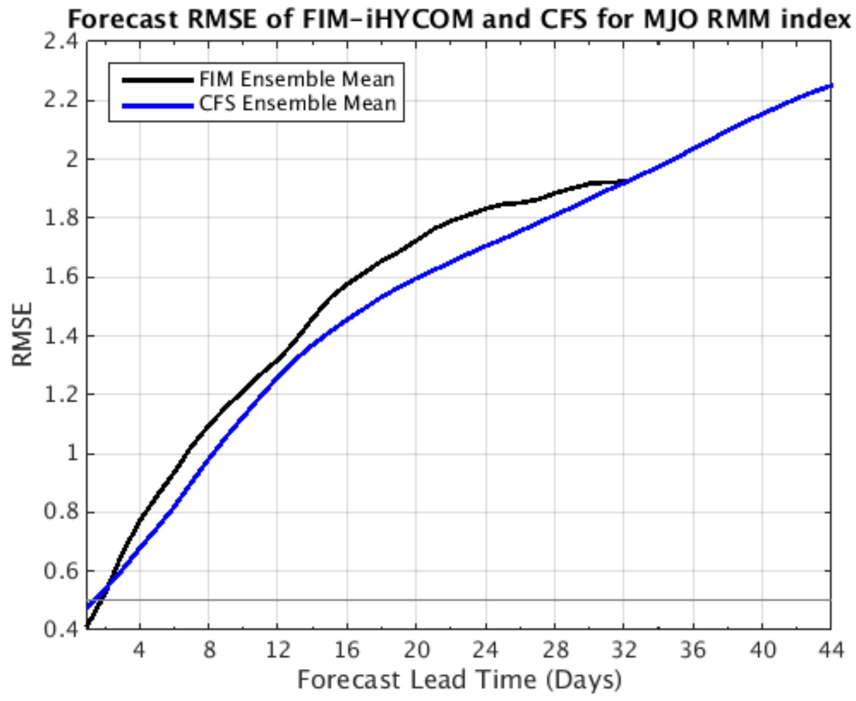
FIM-HYCOM and CFSv2 coupled model experiments

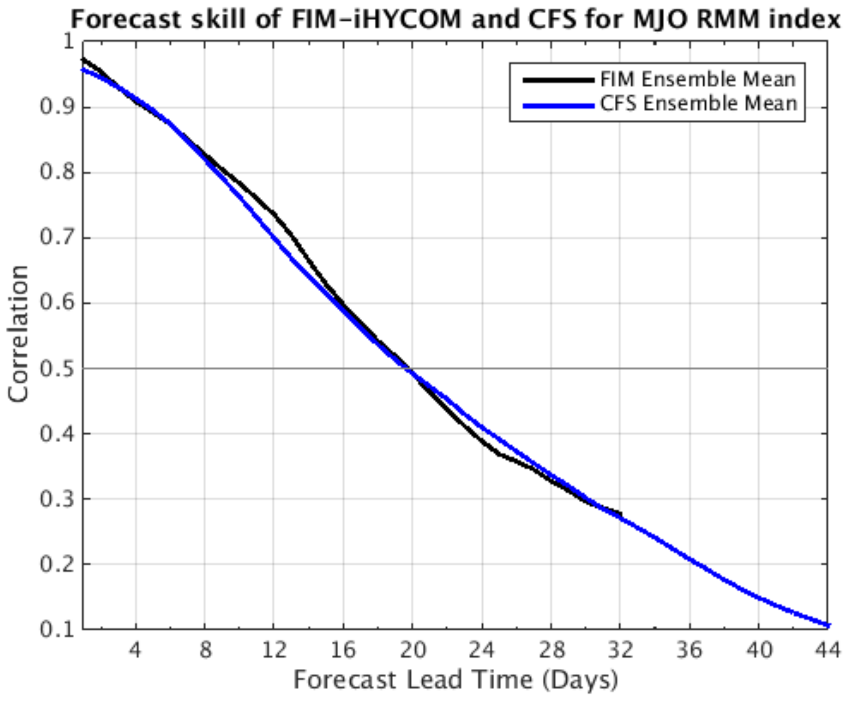
- 1999-2010 retro experiments, 4x/week, 28-day



MJO frequency and case study behavior

MJO – CFSv2 and FIM-HYCOM: Ensemble means



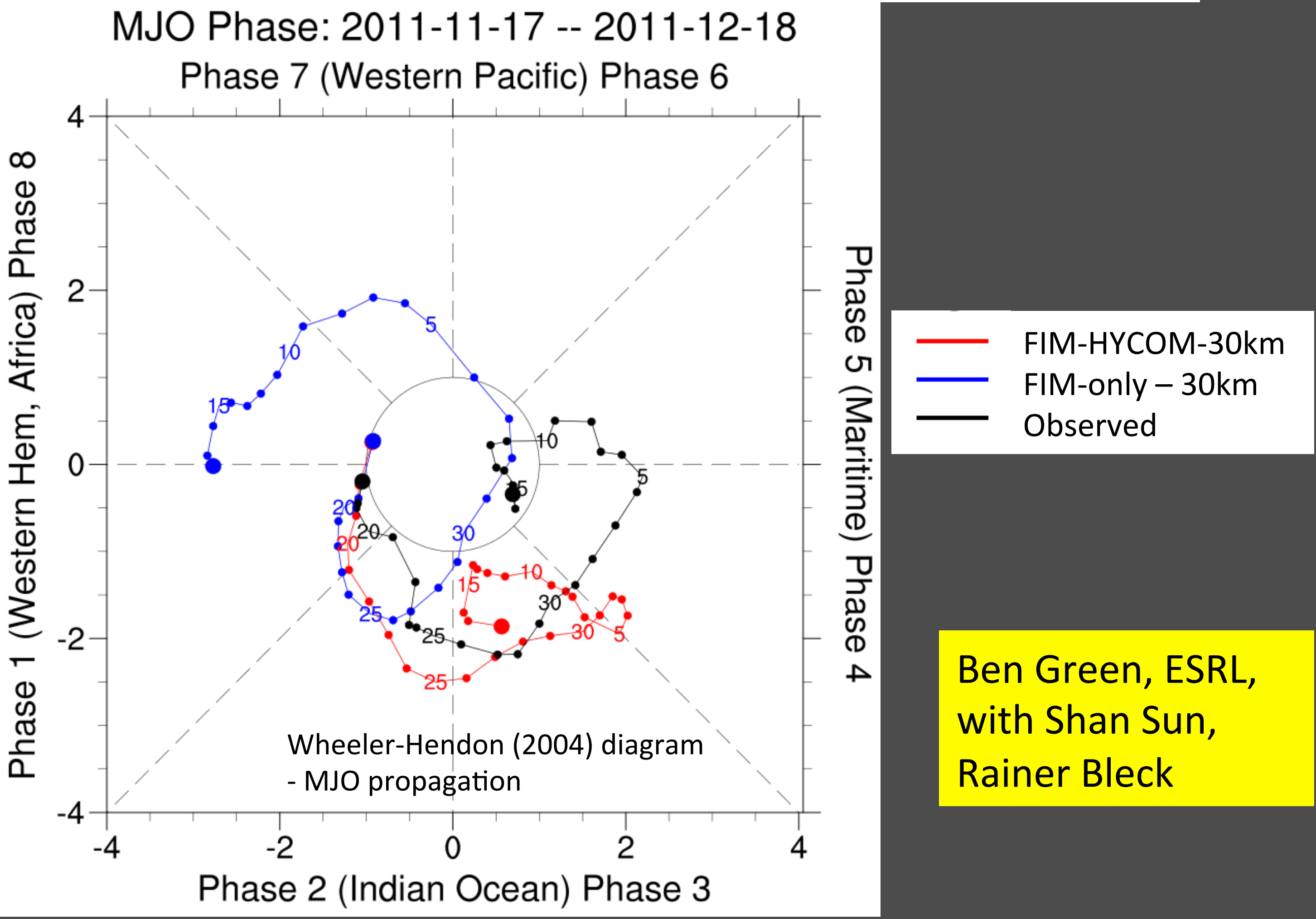


- FIM has nearly identical "skill" as CFSv2 (predictability out to 20 days)
- However, FIM has higher RMSE than CFSv2
- FIM members not yet averaged to common 00z-00z 24h period

Importance of ocean coupling for MJO with FIM/HYCOM coupled model
(Madden-Julian Oscillation)

Importance of ocean coupling

- Compare FIM-iHYCOM and FIM only at 30km resolution and temporary version of Grell-Freitas deep convection with diurnal cycle
- Ocean coupling significantly slows MJO propagation, in better agreement with obs
- **Coupling with an ocean model is crucial in some but not all MJO cases.**



Ben Green, ESRL, with Shan Sun, Rainer Bleck

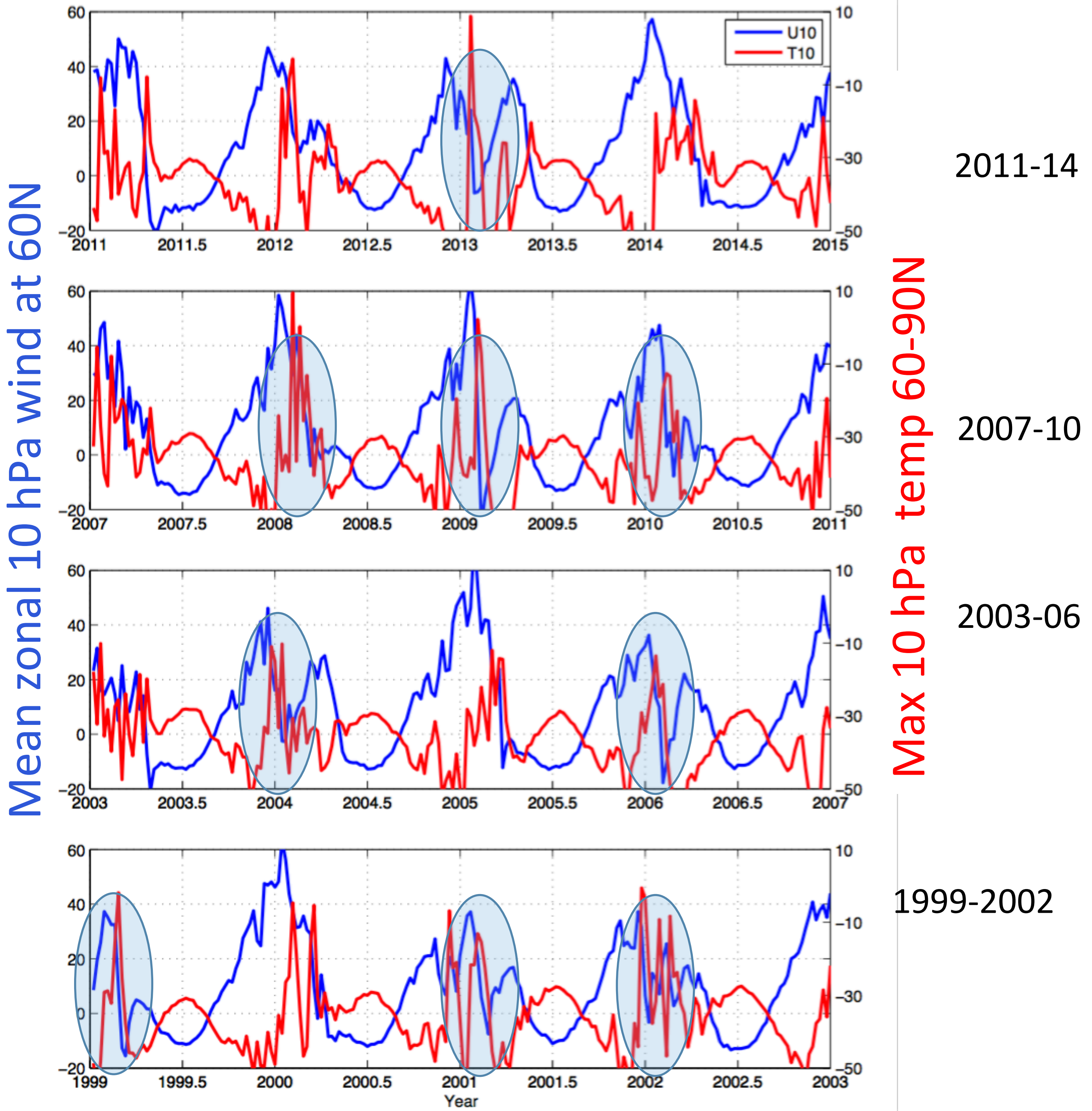
Stratospheric warming event frequency and case study behavior

Observed N. Hemispheric 10 hPa fields over 1999-2014

- mean U(zonal) at 60N
- Maximum temp (60-90N)

Stratospheric event metrics (both at 10 hPa <u>in NH winter</u>)

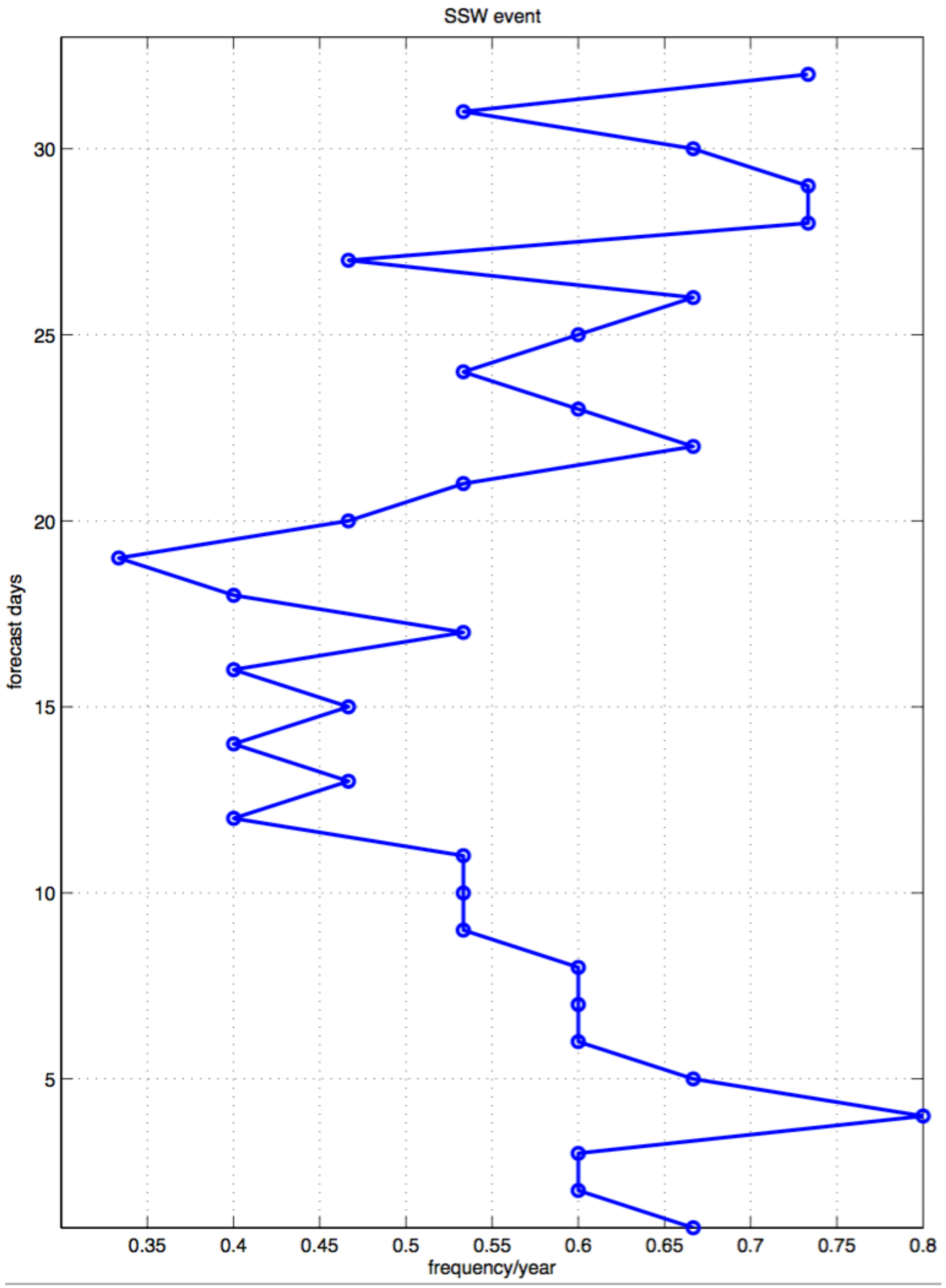
- Mean U(zonal, 60N) < 0
- Max temp (60-90N) > 0 deg C



SSW yearly frequency – FIM forecasts 0-32 day

- during DJFM over 1999-2014
- 00z sampled weekly

- Definition mean U(10 hPa, 50N) < 0



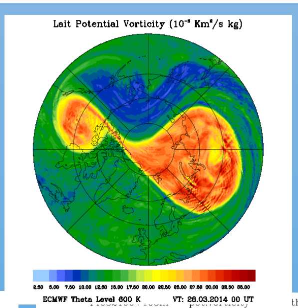
Stratospheric Warming Event – March 2014

Vertical coordinate experiments of different durations comparing
FIM θ-σ (adaptive, ALE – arbitrary Lagrangian-Eulerian) vs.
FIM σ-p (fixed – same as GFS)

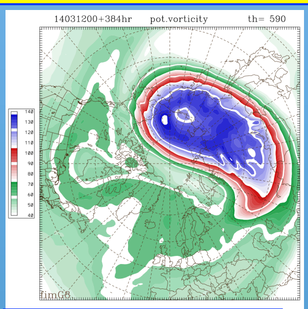
- *Both 21 Mar runs capture breakdown, but only θ-σ* version for 15 Mar 2-week run

Stratospheric vortex split - Late March 2014

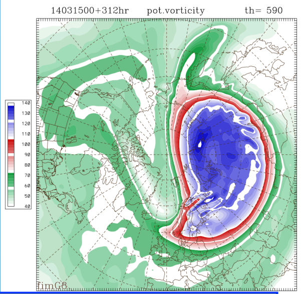
PV - 600K surface



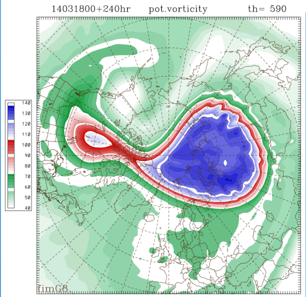
Observed 00 UTC 28 Mar 2014



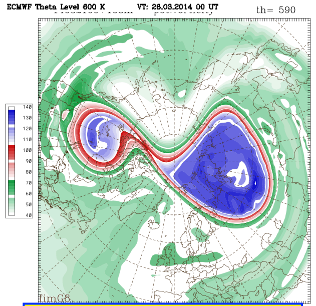
12 Mar init - FIM



15 Mar init - FIM

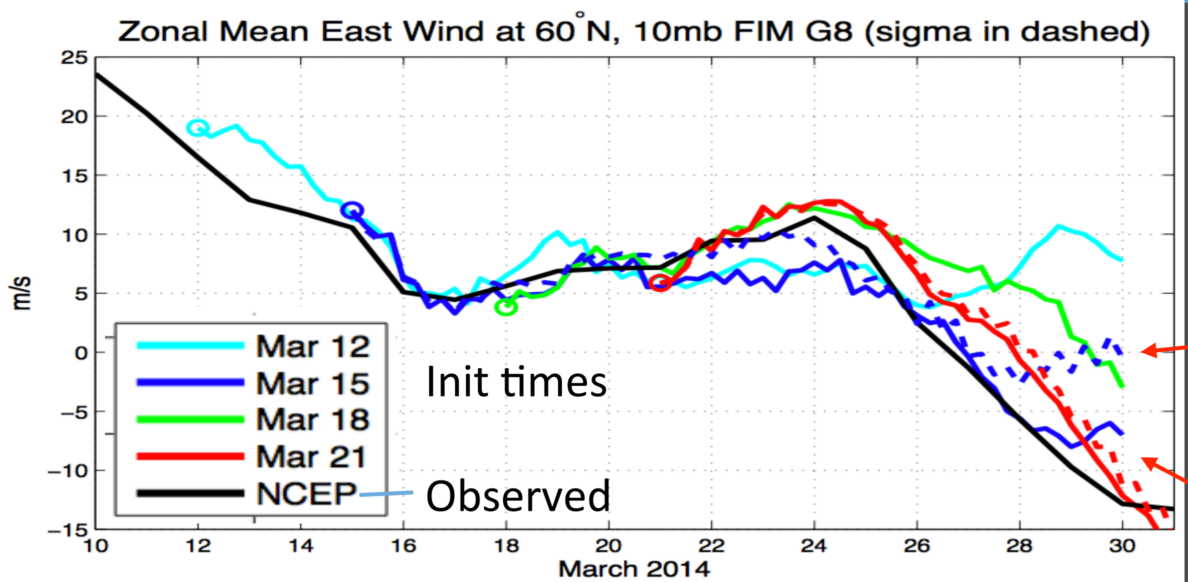


18 Mar init - FIM



21 Mar init - FIM

FIM fcsts valid 00z 28 Mar 2014



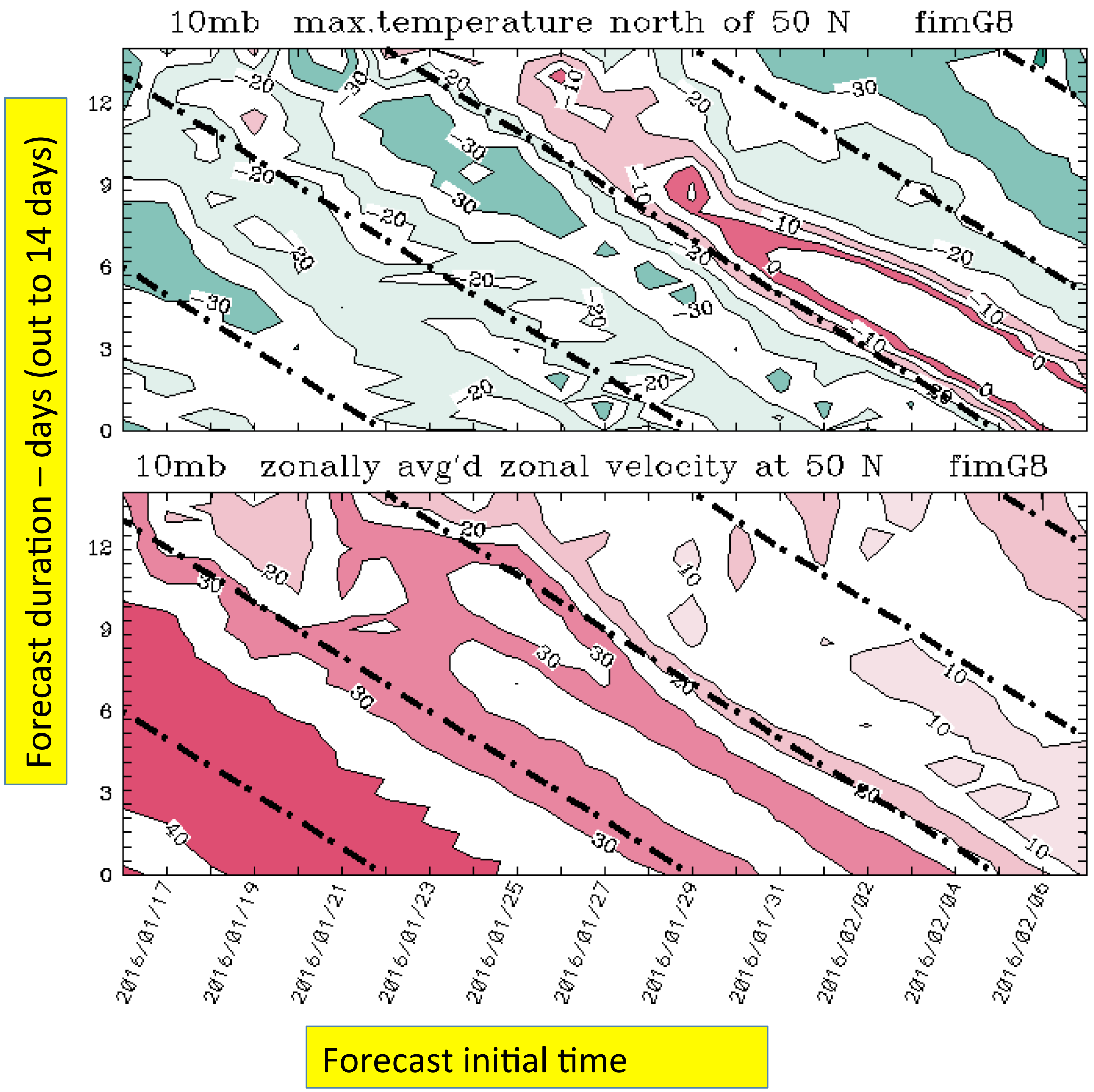
σ-p (dashed) vs. θ-σ (solid)

Mean 10hPa zonal wind @60N – Mar2014 – obs vs.FIM fcsts

Feb 2016 stratospheric event

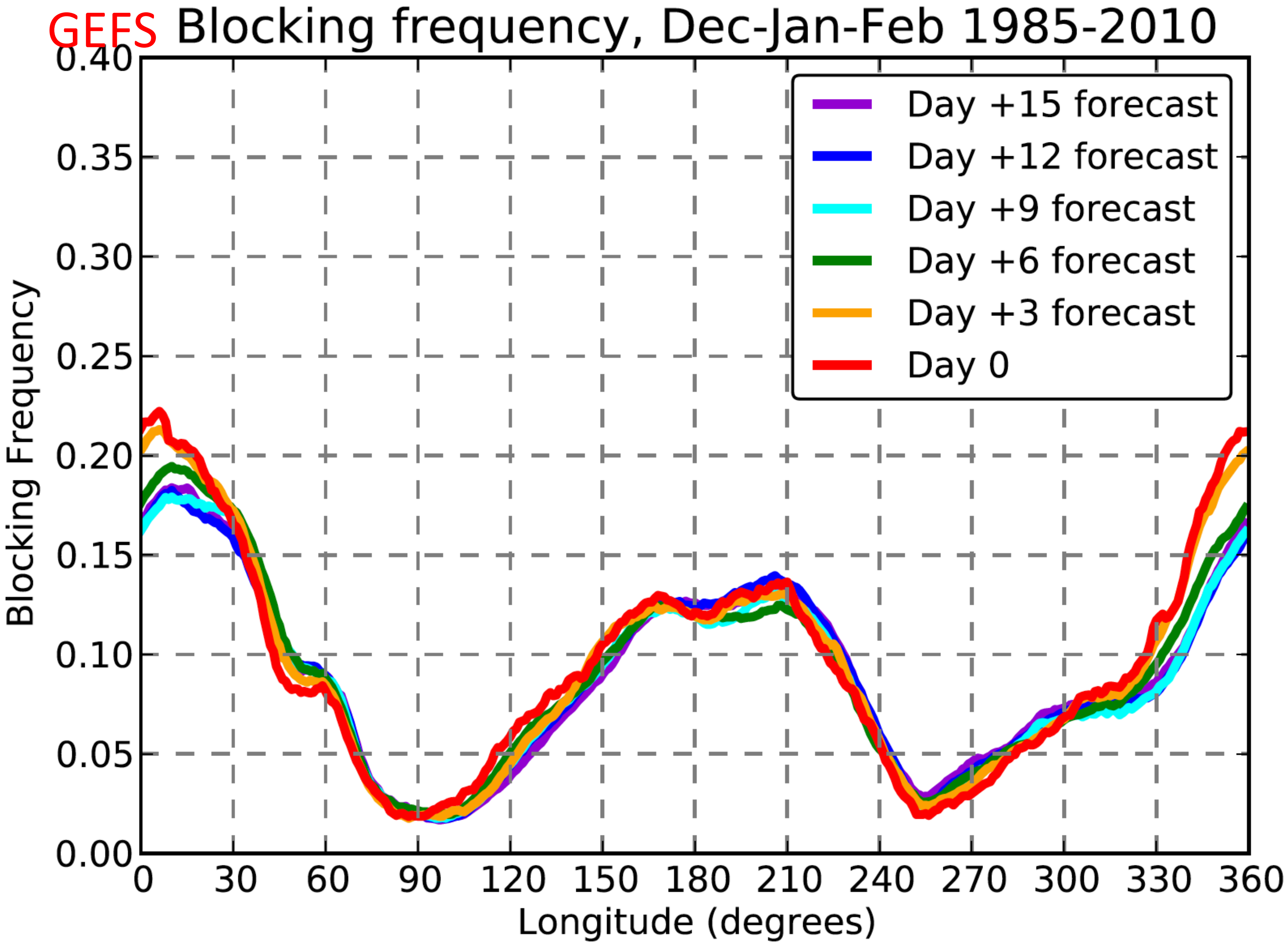
- FIM (atmos only) forecasts
- 17 Jan – 7 Feb 2016

1. Max 10 hPa temp. in 50-90N (polar region)
2. Zonal mean 10 hPa wind at 50N



Preliminary results on blocking

- Hypothesis:
  - Blocking predictability in models is related to predictability of related processes – MJO, stratospheric warming events, Rossby wave breaking, etc.
- Preliminary case study results with FIM-HYCOM
  - MJO prediction requires ocean coupling in some but not all cases
  - SSW prediction duration (NWP case) improved by ALE vertical coordinate (not sigma)
  - NWP testing of atmosphere component useful for identifying GWD, land-use
- Week 3-4 blocking process frequency studies started- CFSv2, FIM-HYCOM
  - Initial 16-yr retrospective experiment with FIM-HYCOM just completed
  - Frequency determined for
    - Blocking – 1) mid-troposphere (Tibaldi-Molteni) and 2) tropopause (Pelly-Hoskins)
    - MJO, and SSW frequencies
- Future experiments - sensitivity of these blocking processes to
  - Physical parms (convection, grav wave drag, subgrid cloud, etc.), horizontal and vertical resolution, numerics – FIM/HYCOM, NMME incl. CFSv2, future NGGPS



Tom Hamill
37th Climate Diagnostics and Prediction Workshop, 2012

Under-forecasting of Atlantic block frequency after day +3

Key research questions for stationary waves/blocking - ESPC

1. What is **predictability (using week-month-90day time-averaging) at week-3 to month-9** (NMME range) of blocking and stationary waves from **existing global models** (especially GEFS and CFSv2, FIM-iHYCOM, NMME models)?
2. What is the **minimum horizontal and vertical resolution** needed for global models to capture blocking events and associated processes?
   - Identify sensitivity to model numerics as well as resolution.
3. To what extent is **accurate prediction of the following phenomena** necessary for predicting onset/cessation of stationary wave events?
   - MJO, stratospheric warming events?
   - Subtropical jets (existence, preservation)?
   - Tropospheric Rossby wave-breaking?
4. To what extent is over- or under-prediction of blocking dependent on model physics suite? (e.g., formation – deep convection? decay – primarily radiation?)